



Personal UV exposure on a ski-field at an alpine site

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**Personal UV
exposure**

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Personal UV exposure on a ski-field at an alpine site

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Abstract

Mountain sites experience enhanced ambient UV radiation levels due to the concurrent effects of shorter radiation path-length, low aerosol load and high reflectivity of the snow surfaces.

5 This study was encouraged by the possibility to collect data of personal UV exposure in the mountainous areas of Italy, for the first time. Personal UV exposure (expressed in terms of Exposure Ratio, ER) of two groups of volunteers (ski instructors and skiers) at the Alpine site of La Thuile (Valle d'Aosta region, Italy) was assessed using polysulphone dosimetry which was tested in a mountainous snow-covered environment. In
10 addition measurements of biological markers of individual response to UV exposure such as skin colorimetric parameters were carried out.

It was found that snow and altitude of study site affect calibration curves of polysulphone dosimeters in comparison to a situation without snow.

15 The median ER, taking into account the whole sample, is 0.60 in winter, with a range of 0.29 to 1.46, and 1.02 in spring, ranging from 0.46 to 1.72. There are no differences in exposures across skiers and instructors in spring while in winter skiers experience lower values. UV exposures are not sensitive to the use of sunscreen across instructor/skier group by day or by seasons or by photo-type. With regard to colorimetric parameters, the main result was that both skiers and instructors had on average
20 significantly lower values of L^* and b^* after exposure i.e. becoming darker but the inappropriate sunscreen use did not reveal any changes in skin colorimetric parameters except in one spring day.

25 In conclusions UV intensities on the ski-fields are often significantly higher than those on horizontal surfaces. Given the high levels of exposure observed in the present study, dedicated public health messages on the correct sunscreen use should be adopted.

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1 Introduction

The amount of solar ultraviolet (UV) radiation at the Earth's surface depends on the incoming solar energy and the transmission properties of the atmosphere as well as the features of the site such as surface topography, orientation and albedo (Kerr, 2003).

5 Mountain sites experience enhanced ambient UV radiation levels due to the concurrent effects of shorter radiation path-length, low aerosol load and high reflectivity of the snow surfaces. The Alps are one of the places where the highest values of UV levels in Europe are experienced (Meloni et al., 2000; Schmucki and Philipona, 2002; Seckmeyer et al., 2007) and tourism is leading more and more people onto ski fields
10 with the result in skin damage due to UV overexposure of the body parts not usually protected by clothing such as the nose, mouth, chin, cheeks and eyes.

Studies of UV radiation at high altitude sites have been carried out in Europe since the 1960s (Blumthaler and Ambach, 1988; Blumthaler et al, 1997; Schmucki and Philipona, 2002; Pfeifer et al., 2006) showing that highest UV irradiances occur due to synergic effect of the altitude and the reflection from snow and hence the upward radiation can be comparable with the incoming radiation. In general standard measurements
15 of ground based UV radiation are related to horizontal surfaces (ambient irradiance) over a specified period of time (ambient dose) and carried out by well-calibrated instruments (spectroradiometers, broad-band and narrow-band radiometers). The quantification of UV exposure of human skin indeed requires measurements of erythema
20 doses (Parisi, 2005) on tilted surfaces. Only a few systematic UV measurements for differently oriented surfaces are available (Schauberger, 1990; Webb et al, 1999). Openrieder et al., (2003) developed and built a new automatic system to measure radiation fluxes in 27 positions at three different altitude sites in Germany in order to have quantitative UV data related to the directions of the oriented surfaces of human body
25 in different environment conditions. Dosimetry is a technique used to quantify personal solar UV exposure of humans in different settings, during their ordinary activity. The most widely used UV dosimeters are polysulphone (PS) films which have a response

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to UV radiation similar to human skin (Diffey, 1989; Webb, 1999; Kimlin, 2003, 2005).

To our knowledge little is known about UV exposure of professional outdoor workers at high altitude sites and recreational alpinists (e.g. skiers) who presumably receive the highest personal doses. Epidemiological studies showed that skiers are at an increased risk for the squamous cell carcinoma (Rosso et al., 1999). Furthermore PS dosimetry studies have not been carried out at high altitude sites so far. In fact to cite but a few: in Moehrle et al. (2000) and Moehrle et al. (2003), the occupational UV exposure of mountain guides and ski instructors in the Alps (2000) and only of mountain guides (2003) were assessed using *Bacillus subtilis* spore film dosimeters. They found that UV levels in these occupations exceed international limits of exposure (80 J/m² per 8 h working period) from nine to 53 times. High UV exposure levels of professional ski instructors were measured using digital dosimeters at Vail, Colo, USA, (Rigel et al., 2003). Allen and McKenzie (2005) measured the UV exposure at the Mount Hutt ski-field (2000 m a.s.l.) in New Zealand and compared with the values measured at the same time in a nearby sea level site in Christchurch city using a single electronic dosimeter. They found that at the ski-field UV intensities on horizontal surfaces were 20–30% greater than at the sea site; personal UV doses were significantly greater than those on horizontal surfaces. The same authors, in the second measurement campaign at Mt Hutt ski-field (2006) confirmed the overall results of their previous study.

Thus, the aim of our work was to assess personal UV exposure using polysulphone dosimetry of two groups of skiers (ski instructors and skiers) at the Alpine ski field of La Thuile-Les Suches (2100 m a.s.l.) in Valle d'Aosta region (Italy). This region is located in the far north- west of Italy and it has the peculiarity that the territory is at an average height of 2000 m a.s.l. This study aimed to collect data of personal UV exposure in the mountainous areas of Italy, and to test polysulphone dosimetry in that intense UV radiation environment.

In addition, as in our previous study with sunbathers (Casale, 2007) we aimed to measure colorimetric parameters before and after exposure on an exposed and on a non-exposed site. Colorimetric measurements were taken into account to evaluate

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2 Materials and Methods

2.1 Study location

A spring (30 March–4 April 2006) and a winter (29–30 January 2007) field campaigns were carried out at La Thuile-Les Suches ski field (45.7° N, 6.6° E, 2100 m a.s.l.) which has mostly ski slopes oriented towards east direction. During the campaigns the maximum UV index was 6.0 in spring days and 2.0 in winter days (the mean UV indexes in those periods under clear sky condition are 5.0 and 1.5 respectively, see <http://www.uv-index.vda.it/>).

2.2 Study participants

Two skier groups were selected for this study: skiers were recruited among the staff of the ARPA Valle d'Aosta (Aosta Valley Regional Environmental Protection Agency) using an advertisement at the ARPA headquarter at Saint-Christophe (Aosta). Instructors were recruited voluntary at La Thuile ski school.

A total number of 62 adults (31 skiers and 31 instructors), aged 20–69 years participated in the campaigns. Some skiers as well as some instructors participated in multiple days in the spring campaign, some of them only in the spring or the winter campaign and some of volunteers participated in both campaigns. In addition the research team of Sapienza-University of Rome, on the basis of the observation of hair and eye colours, skin pigmentation and questions on burning and tanning tendency, diagnosed the photo-type of participants according to the classification of Fitzpatrick skin types (WHO, 2006), before each field campaign.

In addition each participant was asked to complete a questionnaire about time intervals spent in the shade and indoor (Appendix A) at every PS change (approximately

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every 2 h). The participants were also asked about their sunscreen use at the beginning and at the end of their exposure.

2.3 Ambient UV dose measurements

Ambient erythema ultraviolet doses were measured using the well calibrated broad-band UV-S-AE-T radiometer (Kipp&Zonen, The Netherlands), installed, for both field campaigns, on the roof of the building of Espace S. Bernardo cable car directly on the ski-field at La Thuile-Les Suches (45.7° N, 6.6° E, 2100 m a.s.l.).

In addition UV doses were also recorded by a broad-band radiometer (model UVB-1, Yankee Environmental System, MA, USA) at Saint Christophe, Aosta (45.8° N, 7.4° E, 569 m a.s.l.), and by a second UV-S-AE-T broad band radiometer at Les Granges (45.7° N, 6.6° E, 1640 m a.s.l.). The radiometers have a spectral response similar to that of skin erythema and they provide the erythema dose rate between 280 and 400 nm at 1 minute averages. All UV instruments belong to ARPA Valle d'Aosta.

2.4 Polysulphone dosimetry

The use of PS dosimeters requires the determination of the calibration curve i.e. ambient dose versus change in PS film absorbance (ΔA at 330 nm), prior and post exposure in each experiment. The curve can be parameterized by a coefficient, c , multiplying a cubic polynomial function (Diffey, 1984; Diffey, 1989):

$$D = c \left(\Delta A + \Delta A^2 + \Delta A^3 \right) \quad (1)$$

where D (erythema dose) is expressed in kJm^{-2} . The uncertainty on D was estimated to be 10%.

This curve can be determined in situ or it can be derived once total ozone and solar zenith angle are known to take into account the local environmental conditions of the site (Casale et al., 2006). Three different altitude sites were chosen in order to study

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the albedo and altitude effect on polysulphone calibration curves: the lowest site of Saint Christophe, at Les Grange and at La Thuile-Les Suches ski field.

2.5 Exposure Ratio

Using the calibration curve it is possible to determine personal doses and hence Exposure Ratio (ER is defined as the difference between the erythemally weighted absorbed dose as measured by the PS dosimeter worn by the volunteers, and the corresponding ambient dose on a horizontal plane provided by the radiometers, for each time slot). On the days of campaigns, each participant was equipped with a 40 μm -thick polysulphone (PS) film mounted in a plastic holder with a central hole of about 1 cm^2 . We chose a vertically oriented dosimeter (a high UV-exposed site), attached to the cap (Fig. 1). Such vertical orientation can register both the incident UV radiation from the sun at moderately low solar elevation angles and UV radiation reflected from the snow. PS dosimeters were changed approximately every two hours in order to avoid saturation (10:00–12:00, 12:00–14:00, 14:00–16:00 LT (Local Time)) and ER calculated for each time period.

It has to be noticed that personal doses during skiing depend on changes in altitude and orientation of ski slopes and they cannot be correlated to measurements of ambient UV radiation at a specific chosen location. In this study exposure was expressed in terms of Exposure Ratio, hence personal doses were normalized to the ambient dose at the altitude of 2100 a.s.l. (La Thuile). The uncertainty of ER was estimated to be 20% including the variability of different altitude of ski slopes.

2.6 Skin colour measurements

For each participant, measurements of skin colour on the forearm (constitutive pigmentation) and on a high exposed site, the cheek, were carried out before and after the exposure using a Minolta spectrophotometer (model CM26000d). This instrument was used since it is recommended for the objective measurement of skin pigmentation

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(Park et al., 2002). It is based on physical measurement of reflected light, through an integrating sphere, at specific wavelengths (400–700 nm at 10 nm steps) which correspond to the spectrum of visible light. A number of light filters are built in the instrument. Results are displayed as a graph showing reflectance vs. wavelength. With this instrument it is possible to obtain Commission Internationale de l'Eclairage (CIE) colorimetric values in terms of: L^* , (luminance), which gives the relative brightness on a scale from 0 (black) to 100 (white); a^* , which represents the balance between red (positive value) and green (negative value); b^* , which represents the balance between yellow (positive value) and blue (negative value).

2.7 Statistical analysis

Data were analysed using the Statistical Package for Social Sciences (SPSS) software version 14.0. The Wilcoxon Signed Rank test (WSR) was used as a non-parametric alternative to the repeated measures t-test to test for differences within groups (skiers and instructors) of the measures of ER, $L^*a^*b^*$ and pre and post sun exposure. The Friedman test was used as a non-parametric alternative two-way repeated measures analysis of variance by ranks to detect differences in ER across multiple time slots (repeated measures) with the WSR to test for the specific differences between each time slot. Statistical significance was set at $p \leq 0.05$ (two-tailed).

3 Results and discussion

3.1 Study participants

This study involved 62 participants (31 instructors and 31 skiers): 47 males and 15 females with a median age of 40 years ranging from 20 to 66 years. There were 11 and 4 females among skiers and instructors respectively. 33.9% (16 males and 5 females) of volunteers had skin Type II, (fair skinned Caucasians who burn easily and

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tan slowly and with difficulty) while 66.1% (31 males and 10 females) had skin Type III (medium skinned Caucasians who burn rarely and tan relatively easily).

A total number of 13 adults (6 instructors and 7 skiers) participated only in the winter campaign, 30 adults (19 instructors and 11 skiers) only in the spring campaign. There were indeed 19 participants (6 instructors and 13 skiers) in both seasons. A season group cross-tabulation is reported in Table 1.

Over the whole study period, 11 skiers and 14 instructors participated in one spring day, 13 skiers and 6 instructors in two spring days, 5 instructors in three spring days, 7 skiers and 6 instructors in one winter day. Taking into account both seasons, 9 skiers participated for a total of three study days (two days in spring and one in winter), 6 instructors and 4 skiers participated for a total of two study days.

All skiers wore three dosimeters which were changed approximately every two hours in both campaigns. Ten instructors used two dosimeters and only two instructors wore the third dosimeter in spring. In winter instructors wore only one dosimeter during the time slot from 10:00 to 12:00 LT.

In winter seventeen participants (11 skiers and 6 instructors) applied sunscreen once with sun-protection factor ($SPF \leq 30$) at the beginning of exposure. Only two instructors used very high $SPF (\geq 50)$. In spring thirty participants (18 skiers and 12 instructors) applied sunscreen ($SPF \leq 30$) during the first time slot and seven re-applied sunscreen after noon.

The participants performed their ordinary activity during both campaigns without affecting the use of PS dosimeters.

3.2 Ambient doses

In both campaigns exposure lasted from 10:00 LT to 16:00 LT under almost clear sky conditions (1 April was completely cloudy and on 2 April scattered conditions occurred in the afternoon, but on this day the instructors wore the dosimeters only in the first part of the day). Figure 2 shows the ambient erythral dose rate recorded at La Thuile-Les Suches during the spring campaign. In that period daily total ozone ranged from 330

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DU to 369 DU and solar zenith angles (SZA) were $41^{\circ} < \text{SZA} < 54^{\circ}$. From UV exposure point view the four days can be considered identical. The same occurred for the two winter days with a total ozone of 300 DU and $64^{\circ} < \text{SZA} < 70^{\circ}$.

3.3 Polysulphone dosimetry

5 Measurements of doses for the calibration curve were carried out on 31 March. In that day the comparison among the ambient dose recorded at the three altitude sites showed a percentage differences of 37.7%/1531 m (equivalent to 24%/1000 m) between La Thuile-Les-Suches and Saint Christophe and of 22.1%/1071 m (equivalent 20%/1000 m) between Les Granges and Saint Christophe. It was found that
10 the calibration curves were characterized, for the spring campaign, by a c value of $(1.69 \pm 0.02) \text{ kJm}^{-2}$ at La Thuile-Les Suches, of $(1.47 \pm 0.01) \text{ kJm}^{-2}$ at Les Granges and of $(1.24 \pm 0.01) \text{ kJm}^{-2}$ at Saint Christophe. It can be noticed that the c value is higher for the higher site and all values are higher than those obtained theoretically $(0.94 \pm 0.19) \text{ kJm}^{-2}$ according to Casale's study (2006) when only solar zenith angles
15 and total ozone amounts related to the campaigns were taken into account. When a dedicated measurement campaign, in absence of snow but with similar total ozone amounts, was carried out during fall 2006, it was found that calibration curve was characterized by the c values of $(1.09 \pm 0.06) \text{ kJm}^{-2}$ at Les Granges and of $(0.96 \pm 0.03) \text{ kJm}^{-2}$ at Saint Christophe. Both values resulted within the uncertainty associated to
20 the theoretical values (Casale et al., 2006). This result confirmed the contribution of altitude and multiple reflections from snow resulting in an increase of the c value.

3.4 Exposure Ratio

The first aim of the statistical analysis was only looking at the differences between instructors and skiers. In Table 2 Exposure Ratio results of spring and winter campaigns
25 at each PS dosimeter change (approximately every two hours) are reported in terms of median, minimum (min.) and maximum (max.) values. In spring ER increased in both

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groups during the day from the median value of ER_{10-12} (time period: 10:00–12:00) of 0.96 (skiers) and 0.79 (instructors) to ER_{14-16} (time period: 14:00–16:00) of 1.21 (min: 0.65; max: 1.52) for skiers and of 1.08 (min: 1.00; max: 1.16) for instructors. There were no significant differences across the two groups in their median scores at each time slots (Table 2). Additionally, there were no significant differences in skiers across ER related to the three time slots ($p=0.104$). It was found that there were differences in skiers between ER_{10-12} and ER_{12-14} ($p=0.021$), as well as ER_{10-12} and ER_{14-16} although it did not reach statistical significance ($p=0.055$). The higher ER in the afternoon can be presumably due to exposure of the ski slopes in that time slot in which the reflected radiation can be comparable with the incident radiation.

In winter the median value of ER_{10-12} was 0.96 with a range of 0.29 and 1.46 for instructors. In contrast, skiers had a significant ($p<0.001$) lower value of ER_{10-12} (0.59 ranging from 0.40 to 0.85). Only for skiers, the ER of the three time periods differed from each other ($p<0.001$). There was a marked decrease in ER between time slots 10:00–12:00 and 12:00–14:00 as well as it significant increase between 12:00–14:00 and 14:00–16:00. The median of ER_{12-14} (0.41) was slightly decreased and in the afternoon (ER_{14-16}) the median was 0.69 (min: 0.19, max:1.02). This may be due to the quasi-vertical orientation of the PS dosimeter which received less diffuse and reflected radiation when solar elevation was low in winter.

Results for winter and spring campaigns of Exposure Ratio (ER) averaged over each day together with Exposure Ratio, averaged on two winter days and four spring days, are summarized in Table 3. Within each group, in spring skiers received on average 105% of ambient dose (ranging from 63% to 137%) and instructors 87% of ambient dose (ranging from 46% to 172%), but this difference is not statistically significant ($p=0.129$). In winter the personal dose of instructors is on average 96% of ambient dose which is higher than skiers (54%). The higher winter values are probably due to the kind of activity of instructors in that period in which they had mainly beginners classes and hence they were mainly standing.

Taking into account the overall total whole sample, the median value of ER in winter

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is 0.60, with a range of 0.29 to 1.46, and in spring 1.02, ranging from 0.46 to 1.72.

Looking at the differences across season we took into account only the 19 participants in both seasons and it was found that winter Exposure Ratio was 0.87 (min: 0.29; max: 1.46) and spring ER was 0.63 (min: 0.46; max: 1.22) for instructors while for skiers winter and spring ER were 0.54 (min: 0.42; max: 0.70) and 1.07 (min: 0.81; max: 1.32), respectively. There was not a seasonal significant difference ($p=0.463$) within instructors although the number of instructors was small, while winter ER value is consistently lower ($p=0.01$) than spring ER within the group of skiers. This can be attributed to the fact that in winter most of ski slopes were in the shade (as derived from self-reported questionnaire).

The use of sunscreen and individual photo-type did not seem to affect the skiing behaviour of participants showing non significant variations in ER across instructor/skier group by day and by seasons ($p>0.05$).

To carry out a comparison with different individual UV exposure levels, results of pilot study in a population of Italian sunbathers on the beach in central Italy (Lat.41.8° N, Long.12.2° E, 0 m a.s.l.) were considered. In such environment, the exposed site (chest) received a personal dose ranging from the minimum of 9% for individuals mostly in motion and maximum of 41.7% for those mainly lying of ambient dose (Siani et al., 2007). This information, although a direct comparison cannot be possible, can provide an indication on how exposure on ski-field resulted consistently higher (Table 2).

3.5 Colorimetric parameters

Looking at the differences between instructors and skiers on non exposed site (constitutive pigmentation), L^* , a^* and b^* on forearm in spring and winter campaigns were examined finding no differences across skiers and instructors in winter ($p>0.05$); in spring L^* on non exposed site was significantly ($p=0.036$) different between skiers and instructors. The latter had a lower value of L^* (i.e. darker) probably due to unintentional exposure of forearm during previous days.

The median values together the minimum and maximum of L^* , a^* , b^* on the exposed

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site, pre and post exposure during spring and winter campaigns, for each ski group, are reported in Tables 4 and 5 respectively. Different values of L^* , a^* on the exposed site, both before and after exposure in both seasons ($p < 0.001$) were found across skiers and instructors, while no difference resulted in b^* parameter ($p = 0.089$ in b^* pre exposure and $p = 0.250$ in b^* post exposure). In spring differently from winter, instructors (pre and post exposure) were characterized by lower median L^* and higher median a^* than skiers probably due more time spent outdoors during the previous months.

Both skiers and instructors had on average significantly lower median L^* and b^* after exposure (in spring and winter $p < 0.001$). This can mean that all subjects changed their skin pigmentation after exposure becoming darker (expected result). On the contrary a^* post exposure and pre exposure did not differ in the median score ($p = 0.253$ and $p = 0.06$ in spring and in winter respectively).

When the analysis on post $L^*a^*b^*$ measures was carried out by sunscreen use, it was found that in winter there were no significant differences among participants (instructors or skiers and by photo-type). In contrast on 2 April (Day 5 of the spring campaign), those who used sunscreen (all had photo-type III), experienced a significant higher L^* and lower a^* post exposure ($p = 0.018$ and $p = 0.011$ respectively) comparing with no sunscreen users. Excluding Day 5, spring results did not differ from the winter results. Using this information it seems that sunscreen use at the beginning of exposure or in a few cases twice, was not sufficient to significantly change skin colorimetric parameters across participants. Only Day 5 showed a peculiarity.

The comparison between spring and winter parametric values carried out taking into account only participants in both seasons showed that L^* and a^* pre and post exposure in spring was significantly lower than winter values ($p < 0.002$) while b^* pre and post exposure in spring was significantly higher.

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4 Conclusions

High UV exposure is assumed to be the most important environmental risk factor for development of skin cancer, but quantification of human exposure as well as its baseline-reference is a complex issue (Knuscke et al., 2007).

5 This study was conducted to assess UV exposure in terms of Exposure Ratio in an environment of high ultraviolet light exposure such as a mountainous site in the Alps (La Thuile in Valle d'Aosta). Exposure of skiers and ski instructors in two different periods (low and high UV index) was determined using polysulphone dosimetry which was for first time tested in such kind of environment. This methodology requires a
10 careful quantification of calibration curve under the same atmospheric conditions of exposure of population groups. It was found that snow and altitude of site affect the *c* value of calibration curve which is widely higher than those obtained theoretically under the same total ozone amounts and solar zenith angles.

15 New data in terms of ER for the Italian population were provided. In spring there are no significant differences within and between skiers and instructors. The median ER over all data is 1.02, ranging from 0.46 to 1.72. In winter instructors, due to posture during their ski teaching, received higher dose than skiers (96% of ambient dose against 54% for skiers). The use of sunscreen does not seem to vary ER across instructor/skier group by day and by seasons and by photo-type. With regard to colorimetric parameters, the main result was that both skiers and instructors had on average significantly
20 lower values of *L** and *b** after exposure but the sunscreen use did not affect these values except in one spring day.

25 In conclusions the average personal UV exposure resulted in being the same, and in some cases even more, than the ambient UV dose. This exceeds the values reported in WHO report (2006), ranging from 5% to 15% of total ambient UV radiation and for outdoor workers exposures can reach 20–30%.

The limitations of this study is that did not estimate the cumulative personal doses of skiers and instructors that requires a long time monitoring, neither it is possible to

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extrapolate the results to the entire skiing population, but it may provide relevant information to the future health policy related to sun-related behaviours and sun protection measures to educate individuals in overexposure UV environment regarding the need for appropriate UV protection.

5 **Appendix A**

Questionnaire

Fill in the following questionnaire that will help us to interpret the results of the survey.
Thank you

10

1) Date Name

2)The number of dosimeter you used:

15

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3) Describe your activity during the time interval related to each dosimeter:

Time	At Sun	Partially sunny	Totally in the shadow	Standing	Skiing

20

4) Time spent indoor for each dosimeter

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References

- Allen, M. and McKenzie, R.: Enhanced UV exposure on a ski-field compared with exposures at sea level, *Photochem. Photobiol. Sci.*, 4, 429–437, 2005.
- 10 Allen, M. and McKenzie, R. L. UV exposure on New Zealand ski-fields, in *UV Radiation and its Effects: an update*, Royal Society of New Zealand, Miscellaneous Series, 68, Wellington, 70–71, 2006.
- Blumthaler, M., Ambach, W., and Rillinger, E.: Increase in solar UV radiation with altitude, *J. Photochem. Photobiol. B. Biol.*, 39, 130–134, 1997.
- 15 Blumthaler, M. and Ambach, W.: Human Solar Ultraviolet radiant Exposure in High Mountains, *Atmos. Environ.*, 22, 749–753, 1988.
- Casale, G. R., Borra, M., Colosimo, A., Colucci, M., Militello, A., Siani, A. M., and Sisto, R.: Variability among polysulphone calibration curves, *Phys. Med. Biol.* 51, 4413–4427, 2006.
- Casale, G. R.: Assessment of solar UV exposure in the Italian population, Ph. D. thesis in Biophysics, Sapienza University of Rome, Italy, 113pp., 2007.
- 20 Diffey, B. L.: Personal Ultraviolet Radiation Dosimetry with Polysulphone Film Badges *Photodermatol.*, 1, 151–157, 1984.
- Diffey, B. L.: Ultraviolet Radiation dosimetry with polysulphone film. *Radiation Measurement in Photobiology*, London Academic Press, 135–159, 1989.
- 25 Kerr, J. B.: Understanding the factors that affect surface UV radiation *Proc. SPIE, Ultraviolet Ground and Space based measurements, models and effects III*, San Diego August 2003, 5156, 1–14, 2003.
- Kimlin, M. G.: Techniques for assessing human UV exposures. *Proc. SPIE, Ultraviolet Ground and Space based measurements, models and effects III*, San Diego August 2003, 5156, 197–206, 2003.
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- Kimlin, M. G.: Exposure to UV radiation and human health, Proc. SPIE, Ultraviolet Ground and Space based measurements, models and effects V, San Diego August 2005, 5886, N1–8, 2005.
- Knuschke, P., Unverricht, I., and Ott, G. : “Baseline –Reference of solar UV Exposures” to assess individual UV exposure levels in the population, Proc. of the UV Conference, One Century of UV Radiation Research, Davos, Switzerland, September, 127–128, 2007.
- Meloni, D., Casale, G. R., Siani, A. M., Palmieri, S., and Cappellani, F.: UV dose patterns in Italy, Photochem. Photobiol., 71, 681–690, 2000.
- Moehrle, M., Korn, M., and Garbe, C.: Bacillus subtilis spore film dosimeter in personal dosimetry for occupational solar ultraviolet exposure, Int. arch. Environ. Health, 73, 575–580, 2000.
- Moehrle, M., Dennenmoser, B., and Garbe, C.: Continuous Long-term monitoring of UV radiation in professional mountain guides reveals high exposure, Int. J. Cancer, 103, 775–778, 2003.
- Oppenrieder, A., Hoeppe, P., Kopeke, P., Reuder, J., Seefeldner, M., and Rabus, D.: Measuring UV-radiation on inclined surfaces, Proc. SPIE, Ultraviolet Ground and Space based measurements, models and effects III, San Diego August 2003, 5156, 339–342, 2003.
- Pfeifer, M. T., Koepke, P., and Reuder, J.: Effects of altitude and aerosol on UV radiation, J. Geophys. Res., 111, D01203, doi:10.1029/2005JD006444, 2006.
- Parisi, A. V.: Physics concepts of solar ultraviolet radiation by distance education, Eur. J. Phys., 26(2) 313–320, 2005.
- Rigel, E. G., Lebwohl, M. G., Rigel, A. C., and Rigel, D. S.: Ultraviolet Radiation in Alpine Skiing, Arch.Dermatol., 39, 60–62, 2003.
- Rosso, S., Joris F., and Zanetti R.: Risk of basal and squamous cell carcinoma of skin in Sion, Switzerland: a case –control study, tumori, 85, 435–442, 1999.
- Schauburger, G.: Model for the global irradiance of the solar biologically effective ultraviolet radiation on inclined surfaces, Photochem. Photobiol., 52(5), 1029–1031, 1990.
- Schmucki, D. A. and Philipona, R.: Ultraviolet radiation in the Alps: the altitude effect, Opt. Eng., 41(12) 3090–3095, 2002.
- Seckmeyer, G., Pissulla, D., Glandorf, M., et al.: Variability of UV irradiance in Europe, Photochem. Photobiol., 83, 1–8, 2007.
- Webb, A. R., Weihs, P., and Blumthaler, M.: Spectral UV irradiance on vertical surface: a case study, Photochem. Photobiol., 69(4), 464–470, 1999.
- Webb, A.: Solar UVB Instrumentation and Applications Amsterdam, Gordon and Breach Sci-

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ence Publishers, Amsterdam, the Netherlands, 1998.
World Health Organization: Environmental Burden of Disease Series, No. 13. Geneva: edited
by: A. Prüss-Üstün, H. Zeeb, C. Mathers, and M. Repacholi, 1–250, 2006.

ACPD

8, 2745–2769, 2008

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Table 1. Season group cross-tabulation. Count indicates the number of individuals participating in the campaigns. Individuals participated in both seasons are different from those participating in only one season.

Season		Group		Total
		Instructor	Skier	
Winter only	Count	6	7	13
	% within Group	19.4	22.6	21.0
Spring only	Count	19	11	30
	% within Group	61.3	35.5	48.4
Both seasons	Count	6	13	19
	% within Group	19.4	41.9	30.6
Total	Count	31	31	62
	% within Group	100.0	100.0	100.0
	% of Total	50.0	50.0	100.0

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Table 2. Median, minimum and maximum Exposure Ratio (ER), at each PS dosimeter change approximately every two hours. ER_{10-12} (time period 10:00–12:00 LT); ER_{12-14} (time period: 12:00–14:00 LT); ER_{14-16} (time period: 14:00–16:00). Significance level is 0.05.

		Winter				Spring			
Group		Age	ER_{10-12}	ER_{12-14}	ER_{14-16}	Age	ER_{10-12}	ER_{12-14}	ER_{14-16}
Instructor	Median	44	.96	–	–	49	.96	.79	1.08
	Minimum	20	.29	–	–	21	.29	.46	1.00
	Maximum	66	1.46	–	–	66	1.46	1.72	1.16
Skier	Median	40	.59	.41	.69	40	.59	.96	1.21
	Minimum	25	.40	.25	.19	25	.40	.32	.65
	Maximum	62	.85	.55	1.02	62	.85	1.33	1.52
Significance			<0.001	–	–		0.274	0.123	0.764

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Table 3. Median, minimum and maximum Exposure Ratio (ER), averaged over each day of winter/spring campaign and over winter 2 days and spring 4 days. Day 1=29 January 2007; Day 2=30 January 2007; Day 3=31 March 2006; Day 5=2 April 2006; Day 6=3 April 2006; Day 7=4 April 2006.

Group		ER averaged Day 2	ER averaged Winter	ER averaged 2 days	ER averaged Day 3	ER averaged Day 5	ER averaged Day 6	ER averaged Day 7	ER averaged Spring 4 days
Instructor	Median		.96	.96	.77	.88	1.1	1.40	.87
	Minimum		.29	.29	.46	.59	.68	.00	.46
	Maximum		1.46	1.46	1.2	1.34	1.25	1.72	1.72
Skier	Median	.54		.54	.85	1.29		1.23	1.05
	Minimum	.42		.42	.63	1.29		.92	.63
	Maximum	.70		.70	1.18	1.29		1.42	1.37
Total	Median	.54	.96	.60	.83	.95	1.10	1.25	1.02
	Minimum	.42	.29	.29	.46	.59	.68	.00	.46
	Maximum	.70	1.46	1.46	1.19	1.34	1.25	1.72	1.72

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Table 4. Spring campaign: values of $L^*a^*b^*$ pre and post exposure indicated as pre_exp and post_exp respectively.

Group		L*_pre_exp	L*_post_exp	a*_pre_exp	a*_post_exp	b*_pre_exp	b*_post_exp
Instructor	Median	48.76	48.00	15.38	14.84	15.89	15.07
	Minimum	37.84	41.22	10.58	12.50	11.40	11.81
	Maximum	59.12	58.11	18.19	17.73	20.63	19.36
Skier	Median	56.37	55.00	12.17	12.35	16.62	14.44
	Minimum	51.17	50.26	8.09	9.08	13.78	11.67
	Maximum	65.70	60.60	15.20	16.19	20.46	17.20
Total	Median	52.30	51.72	13.82	13.26	16.318	14.78
	Minimum	37.84	41.22	8.09	9.08	11.40	11.67
	Maximum	65.70	60.60	18.19	17.73	20.63	19.36

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Table 5. Winter campaign: values of $L^*a^*b^*$ pre and post exposure, indicated as pre_exp and post_exp respectively.

Group		L*_pre_exp	L*_post_exp	a*_pre_exp	a*_post_exp	b*_pre_exp	b*_post_exp
Instructor	Median	59.33	57.22	13.38	15.22	16.84	14.99
	Minimum	53.61	50.91	10.08	10.84	14.41	12.26
	Maximum	67.28	64.28	17.58	20.74	20.02	17.19
Skier	Median	52.64	51.04	17.17	16.73	16.29	15.18
	Minimum	49.17	46.99	13.99	13.89	13.24	14.00
	Maximum	59.29	58.37	20.04	19.00	18.79	16.95
Total	Median	52.30	51.72	13.82	13.26	16.318	14.78
	Minimum	37.84	41.22	8.09	9.08	11.40	11.67
	Maximum	65.70	60.60	18.19	17.73	20.63	19.36

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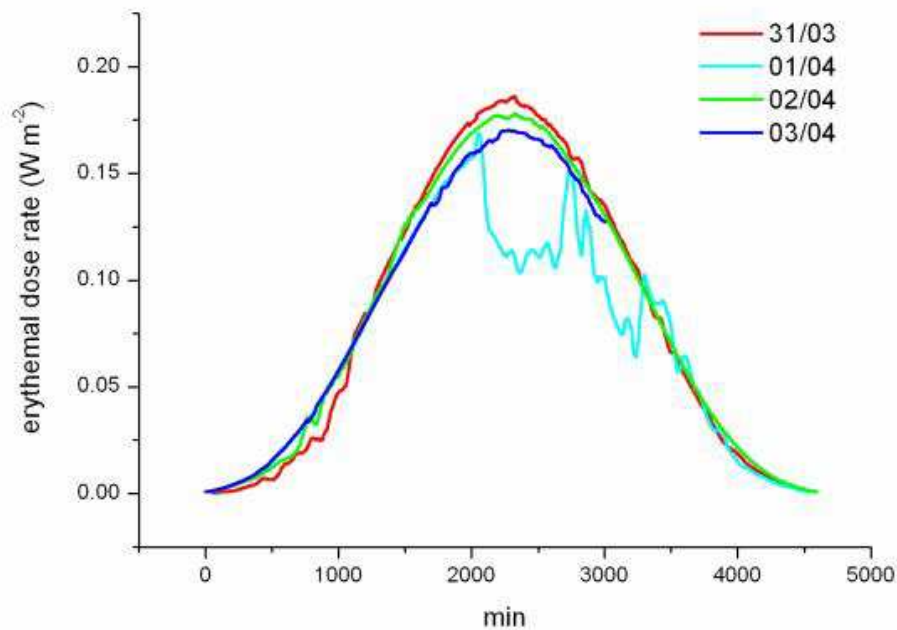
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Fig. 1. Instructor, dosimeter attached to the cap.

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**Fig. 2.** Erythemal dose rate during the spring campaign.[Title Page](#)[Abstract](#)[Introduction](#)[Conclusions](#)[References](#)[Tables](#)[Figures](#)[I◀](#)[▶I](#)[◀](#)[▶](#)[Back](#)[Close](#)[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)